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भाग 10 रैखिकीय मापन की पद्धतियाँ

Indian Standard

PHOTOVOLTAIC DEVICES

PART 10 METHODS OF LINEARITY MEASUREMENT

ICS 27.160

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELH1110002

January 2010 Price Group 5

Solar Photovoltaic Energy Systems Sectional Committee, ETD 28

NATIONAL FOREWORD

This Indian Standard (Part 10) which is identical with I EC 60904-10 :1998'Photovoltaic devices — Part 10: Methods of linearity measurement' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Solar Photovoltaic Energy Systems Sectional Committee and approval of the Electrotechnical Division Council.

The text of the IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60891 : 1987 Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic (PV) devices	IS 12763 : 1989 Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices	Identical
IEC 60904-2 : 1989 Photovoltaic devices — Part 2: Requirements for reference solar cells	IS 12762 {Part 2): 1993 Photovoltaic devices: Part 2 Requirements for reference solar cells	do
IEC 60904-3 : 1989 Photovoltaic devices — Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	IS 12762 (Part 3) : 1998 Photovoltaic devices: Part 3 Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	do
IEC 60904-9 : 1995" Photovoltaic devices — Part 9: Solar simulator performance requirements	IS 12762 (Part 9) : 2010 Photovoltaic devices: Part 9 Solar simulator performance requirements	Technically Equivalent
IEC 61215 :1993 2) Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval	IS 14286 : 2009 Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval *(first revision)*	do
IEC 61646 :1996 Thin-film terrestrial photovoltaic (PV) modules — Design qualification and type approval	IS/IEC 61646:1996 Thin-film terrestrial photovoltaic (PV) modules — Design qualification and type approval	Identical

"Since revised in 2007.
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IS 12762 (Part 10) : 2010
IEC 60904-10 : 1998

Indian Standard

PHOTOVOLTAIC DEVICES

PART 10 METHODS OF LINEARITY MEASUREMENT

1 Scope and object

This part of IEC 60904 describes procedures used to determine the degree of linearity of any photovoltaic device parameter with respect to a test parameter. It is primarily intended for use by calibration laboratories, module manufacturers and system designers.

Photovoltaic (PV) module and system performance evaluations, and performance translations from one set of temperature and irradiance conditions to another frequently rely on the use of linear equations {see IEC 60891 and IEC 61829). This standard lays down the linearity requirements and test methods to ensure that these linear equations will give satisfactory results. Indirectly, these requirements dictate the range of the temperature and irradiance variables over which the equations can be used.

The methods of measurement described in this standard apply to all PV devices and are intended to be carried out on a sample or on a comparable device of identical technology. They should be performed prior to all measurement and correction procedures that require a linear device. The methodology used in this standard is similar to that specified in IEC 60891 in which a linear (straight-line) function is fitted to a set of data points using a least-squares fit calculation routine. The variation of the data from this function is also calculated, and the definition of linearity is expressed as an allowable variation percentage.

A device is considered linear when the following conditions are met over the temperature and irradiance range of interest. Typically, this range of temperature is 25 °C to 60 °C minimum, and the irradiance range of 700 Wm~^{2} to 1 000 Wm~^{2} minimum.

a) For the curve of short-circuit current versus irradiance, the normalized standard deviation of the slope *(б* s */m)* should be less than 0,02.

b) For the curve of open-circuit voltage versus the logarithm of irradiance, the normalized standard deviation of the slope (б$_{s}$/m) should be less than 0,05.

c) For the curve of open-circuit voltage and short-circuit current versus temperature, the normalized standard deviation of the slope (<J$_{s}$/m) should be less than 0,1.

d) The variation of relative spectral response at a specified voltage is less than 5 % for the wavelength band.

NOTE 1 - Many of the IEC PV standards require spectral mismatch corrections which in turn require spectral response measurements. Therefore, the linearity of spectral response with respect to temperature and irradiance is important. It can also be significant for new technologies such as photochemical cells.

NOTE 2 - Because the relative spectral response of some devices such as amorphous silicon varies considerably with voltage, it is important that the linearity determination be performed at a fixed voltage. The voltage selected is governed by the ultimate usage. V_{max} may be selected if the maximum power regime is the area of interest, and for calibration zero bias voltage might be more appropriate

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NOTE 3 - It should be noted that the relative spectral response of some devices varies with temperature and irradiance. Some of these effects may be accounted for as changes in the items a) and c) short-circuit current non-linearity, but some may not be. The item d) requirement accounts for these non-linearities.

General procedures for determining the degree of linearity for these and any other performance parameter are described in clauses 4 through 6.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of (EC 60904. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 60904 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60891:1987, *Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices* Amendment 1 (1992)

IEC 60904-2:1989, *Photovoltaic devices - Part 2: Requirements for reference solar cells*

IEC 60904-3:1989, *Photovoltaic devices ~ Part 3: Measurement principles for terrestrial photovoltaic solar devices with reference spectral irradiance data*

IEC 60904-6:1994, *Photovoltaic devices - Part 6: Requirements for reference solar modules*

IEC 60904-7:1995, *Photovoltaic devices - Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device* (English only)

IEC 60904-8:1995, *Photovoltaic devices - Part 8: Guidance for measurement of spectral response of a photovoltaic (PV) device* (English only)

IEC 60904-9:1995, *Photovoltaic devices - Part 9: Solar simulator performance requirements* (English only)

IEC 61215:1993, *Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval*

IEC 61646:1996, *Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval*

IEC 61829:1995, *Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics*

3 Apparatus

3.1 Test apparatus

The following apparatus is required to control and measure the test conditions:

a) a radiant source (natural sunlight or solar simulator, class B or better in accordance with I EC 60904-9) of the type to be used in subsequent tests;

b) any equipment necessary to change the irradiance over the range of interest without affecting the relative spectral irradiance distribution and the spatial uniformity, such as mesh filters or neutral density filters;

NOTE - The equipment and procedure used to change the irradiance are to be verified with a radiometer. The change in relative spectral irradiance distribution should not result in more than 0.5 % change in the short-circuit current of the device (see IEC 60904-7 and IEC 60904-8). Mesh filters are believed to be the best method for large surfaces.

c) a PV reference device having a known short-circuit current versus irradiance characteristic determined by calibrating against an absolute radiometer in accordance with the relevant IEC standard;

d) any equipment necessary to change the temperature of the test specimen over the range of interest;

e) a means for controlling the temperature of the test specimen and reference device, or a removable shade;

f) a suitable mount for supporting the test specimen and the reference device in the same plane normal to the radiant beam;

g) a means for monitoring the temperature of the test specimen and reference device to an accuracy of ±1 °C, and repeatability of ±0,5 *°C*

3.2 Specimen apparatus

Depending on the performance parameter for which the linearity determination is being made, one or more of the following apparatus items may be required:

a) equipment for measuring the current of the test specimen and reference device to an accuracy of ±0,2 % of the reading;

b) equipment for measuring the voltage of the test specimen and reference device to an accuracy of ±0,2 % of the reading;

c) equipment for measuring the relative spectral response of the test specimen (or a representative sample equivalent to the test specimen) in accordance with IEC 60904-7 to an accuracy of ±2 % of the reading.

NOTE - I EC 60904-7 provides methods for the computation of spectral mismatch error introduced in the testing of photovoltaic devices, and IEC 60904-8 provides guidance for spectra) measurement.

4 Procedure for current and voltage linearity test

There are two acceptable procedures for performing the linearity test of short-circuit current and open-circuit voltage with respect to temperature and irradiance.

4.1 Procedure in natural sunlight

4.1.1 Measurement in natural sunlight shall only be made when

- the total irradiance is at least as high as the upper limit of the range of interest;
- the irradiance variation caused by short-term oscillations (clouds, haze, or smoke) is less than ±2 % of the total irradiance as measured by the reference device; and
- the wind speed is less than 2 ms-^{1}.

4.1.2 Mount the reference device co-planar with the test specimen so that both are normal to the direct solar beam within ±1°. Connect to the necessary instrumentation.

NOTE - The measurements described in the following subclauses should be made as expeditiously as possible within a few hours on the same day to minimize the effect of changes in the spectral conditions. If not, spectral corrections may be required.

4.1.3 If the test specimen and reference device are equipped with temperature controls, set the controls at the desired level. If temperature controls are not used, shade the test specimen from the sun and allow it to stabilize within ±1 °C of the ambient air temperature. The reference device should also stabilize within ±1 °C of its equilibrium temperature before proceeding.

4.1.4 Remove the shade (if used) and immediately take simultaneous readings of the test parameter *X,* the test specimen device parameter *Y* and the temperature and short-circuit current of the reference device.

4.1.5 The irradiance G_0 shall be calculated in accordance with IEC 60891 from the measured current (I_{sc}) of the PV reference device, and its calibration value at STC (I_{rc}). A correction should be applied to account for the temperature of the reference device T_m using the specified temperature coefficient of the reference device α_{rc}.

$$G_o = \frac{1\,000 \times I_{sc}}{I_{rc}} \times \left[1 - \alpha_{rc}\left(T_m - 25\right)\right]$$

4.1.6 If the test parameter being varied is the irradiance, reduce the irradiance on the test specimen to a known fraction k_{i} without affecting the spatial uniformity or the spectral irradiance distribution. There are various methods by which to accomplish this:

a) using calibrated, uniform density mesh filters. If this method is selected, the reference device should remain uncovered by the filter during the operation to enable the incident irradiance to be measured. In this case, k_{i} is the filter calibration parameter (fraction of light transmitted);

b) using uncalibrated, uniform density mesh filters. If this method is selected, the reference device should also be covered by the filter during the test. In this case, k_{i} is the ratio of the reference device short-circuit current (I_{sc}) to its calibration value (I_{rc});

c) by controlling the angle of incidence. If this method is selected, the reference device should have the same reflective properties as the test specimen, and should be mounted co-planar with the test specimen within ±1°. In this case, k_{i} is the ratio of the reference device short-circuit current (I_{sc}) to its calibration value (I_{rc}).

NOTE - The maximum filter mesh opening dimension should be less than 1 % of the minimum linear dimension of the reference device and the test specimen, or a variable error may occur due to positioning.

4.1.7 Calculate the irradiance level on the test specimen G_{i} as follows:

$$G_{\mathrm{i}} - k_{\mathrm{i}} \times G_o$$

where G_0 is determined by the method described in 4.1.5.

4.1.8 If the test parameter being varied is the temperature, adjust the temperature by means of a controller or by alternately exposing and shading the test specimen as required to achieve and maintain the desired temperature. Alternatively, the test specimen may be allowed to warm-up naturally with the data recording procedure of clause 4.1.4 performed periodically during the warm-up.

4.1.9 Ensure that the test specimen and reference device temperature be stabilized and remain constant within ±1 °C and that the irradiance, as measured by the reference device, remains constant within ±2 % during the data recording periods.

4.1.10 Repeat steps 4.1.4 through 4.1.9. The value of the test parameter selected shall be such that the range of interest is spanned in at least four approximately equal increments. A minimum of three measurements shall be made at each of the test conditions.

4.2 Procedure with a solar simulator

NOTE - The use of an emission lamp such as xenon should not be used for the measurement of direct band gap cells. As the band gap changes due to temperature, it can pass through various emission lines in the lamp spectrum and give rise to large shifts in performance. This effect can be minimized by performing a spectral mismatch correction, or by the use of suitable filters.

4.2.1 Mount the test specimen and the reference device co-planar in the test plane of the simulator so that both are normal to the centre line of the beam within ±2°. Connect to the necessary instrumentation.

4.2.2 If the test specimen and reference device are equipped with temperature controls, set the controls at the desired level. If temperature controls are not used, allow the test specimen and reference device to stabilize within ±1 °C of the room temperature.

4.2.3 Set the irradiance at the test plane to the upper limit of the range of interest using the reference device measured current ($/_{sc}$), and its calibration value at STC ($/_{rc}$).

4.2.4 Conduct the test and take simultaneous readings of the test parameter *X*i, the test specimen device parameter *Y*i and the temperature and short-circuit current of the reference device.

4.2.5 The irradiance G_0 shall be calculated in accordance with IEC 60891 from the measured current ($/_{sc}$) of the PV reference device, and its calibration value at STC ($/_{rc}$). A correction should be applied to account for the temperature of the reference device T_m, using the specified temperature coefficient of the reference device a_{rc}.

$$G_o = \frac{1000 \times I_{sc}}{I_{rc}} \times \left[1 - \alpha_{rc}\left(T_m - 25\right)\right]$$

4.2.6 If the test parameter being varied is the irradiance, reduce the irradiance on the test specimen to a known fraction *k*i without affecting the spatial uniformity or the spectral irradiance distribution. There are various methods to accomplish this:

a) by increasing the distance between the test plane and the lamp. With the reference device maintained in the same plane as the test specimen, *k*\ is the ratio of the reference device short-circuit current ($/_{sc}$) to its calibration value ($/_{rc}$);

b) by the use of an optical lens. In this case, *k*\ is the ratio of the reference device short-circuit current ($/_{S}$c) to its calibration value ($/_{rc}$). Care should be exercised to ensure that the lens does not significantly change the relative spectral irradiance in the wavelength range in which the test and reference specimens are responsive;

c) by controlling the angle of incidence. If this method is selected, the distance between the lamp source and the specimen shall be very large to limit the irradiance change across the tilted surface to 0,5 % or less. Also, if this method is selected, the radiant beam shall be collimated, the reference device should have the same reflective properties as the test specimen, and should be mounted co-planar with the test specimen. In this case, *k*\ is the ratio of the reference device short-circuit current ($/_{sc}$) to its calibration value ($/_{rc}$);

d) using calibrated, uniform density mesh filters. If this method is selected, the reference device should remain uncovered by the filter during the operation to enable the incident irradiance to be measured. In this case, k_i is the filter calibration parameter (fraction of light transmitted);

e) using uncalibrated, uniform density mesh filters. If this method is selected, the reference device should also be covered by the filter during the test. In this case, *k*\ is the ratio of the reference device short-circuit current (/$_{sc}$) to its calibration value (/$_{rc}$).

NOTE - The maximum Alter mesh opening dimension should be less than 1 % of the minimum linear dimension of the reference device and the test specimen, or a variable error may occur due to positioning.

4.2.7 Calculate the irradiance level on the test specimen *G*\ as follows:

$$G_i = K_i \times G_o$$

where *Go* is determined by the method described in 4.2,5.

4.2.8 if the test parameter being varied is the temperature, adjust the temperature by appropriate means (see 10.4 of IEC 61215 and IEC 61646).

4.2.9 Ensure that the test specimen and reference device temperature be stabilized and remain constant within ±1 °C during the test.

4.2.10 Repeat steps 4.2.4 through 4.2.9. The value of the test parameter selected shall be such that the range of interest is spanned in at least four approximately equal increments. A minimum of three measurements shall be made at each of the test conditions.

5 Procedure for spectral response linearity test

The relative spectral response of a photovoltaic (PV) device is measured by irradiating it by means of a narrow-bandwidth light source at a series of different wavelengths covering its response range, and measuring the short-circuit current density and irradiance at each of these wavelengths. IEC 60904-7 provides guidance for relative spectral response measurements.

5.1 Special considerations

5.1.1 Preconditioning

- Before the spectral response of amorphous silicon devices Is measured, the device under test shall be stabilized (if necessary), as specified in the tight-soaking test procedure (see IEC 61646).
- Other photovoltaic technologies can require different preconditioning procedures.

5.1.2 This procedure shall be applied to the full-sized test specimen if possible. If this is not possible, a small sample equivalent in construction and materials should be used.

NOTE - The spectral response of a solar cell changes upon encapsulation. Therefore, an encapsulated solar cell should be used if a full-sized module cannot be tested.

5.1.3 When there is an effect of voltage on the relative spectral response, it is desirable to define the following terms which should be used when reporting the results:

- spectral response under load ($S_{V\lambda}$,) the current density at a particular load voltage, generated by unit irradiance at a particular wavelength (AW^{-1}), plotted as a function of

— relative spectral response under load (*k*1. $S_{V\lambda}$) the spectral response under load normalized to unity at the wavelength of maximum response:

$$k_1 \times S_{v\lambda} = \frac{S_{v\lambda}}{S_{v\lambda\mathrm{max}}}$$

The spectral response measurement should be done under the voltage which is appropriate to *the* intended use of the spectral response data. The voltage condition, therefore, shall be specified with the data.

5.2 General procedure

5.2.1 Set the bias voltage on the test specimen to the desired level and maintain this bias voltage within ±3 % of V_{oc}.

5.2.2 Set toe test specimen temperature to the value of interest, and maintain within ±1 °C.

5.2.3 The spectral response measurement should be done under white bias light, similar to the reference AM 1,5 relative spectral distribution of IEC 60904-3. Set the white bias light source irradiance to the value of interest, and maintain within ± 1%.

5.2.4 Measure the relative spectral response over the wavelength intervals of interest. A minimum of three such relative spectral response versus wavelength interval measurements shall be made at this condition (see IEC 60904-7 and IEC 60904-8).

5.2.5 Repeat steps 5.2.3 and 5.2.4 with a new value of irradiance. The value selected shall be such that the range of interest is spanned in at least four approximately equal increments,

5.2.6 Repeat steps 5.2.2 through 5.2.5 with a new value of test specimen temperature. The value selected shall be such that the range of interest is spanned in at least four approximately equal increments.

5.2.7 If desired**,** this procedure may be repeated at other voltages of interest.

6 Linearity calculation

Verify that any variable parameters other than the one being evaluated were held constant during the testing. Small changes in temperature or irradiance may be corrected analytically to the desired condition using IEC 60891. This can be an iterative process which should be updated when linearity is established and when more refined correction coefficients are determined -

6.1 Slope linearity determination

For performance characteristic slopes such as the open-circuit voltage versus temperature, or short-circuit current versus irradiance, calculate linearity using the following method.

6.1.1 Calculate the mean values of the test parameters, and the characteristics of the best-fit straight line using the least-squares fit method.

Step 1: Compute the mean value of the *X* and *Y* data points as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

$$\bar{Y} = \frac{\sum_{i=1}^{n} Y_i}{n}$$

where *n* is the number of measurements.

Step 2: Compute the slope *m* of the best-fit line as follows:

$$m = \frac{\sum_{i=1}^{n} \left(X_i - \bar{X}\right) \; Y_i}{\sum_{i=1}^{n} \left(X_i - \bar{X}\right)^2}$$

Step 3: The best-fit straight line, also known as the regression line, can now be written as follows:

$$\bar{Y} - Y_i = m \times \left(\bar{X} - X_i\right)$$

6.1.2 Compute the variation of the line slope based on the individual data point differences relative to the best-fit straight line.

Step 1: Compute the *AY* difference between each data point and the best-fit straight line at the Xj position:

$$\Delta Y_i = \left(Y_i - \bar{Y}\right) - m \times \left(X_i - \bar{X}\right)$$

Step 2: Compute the AXj difference between each data point and the X mean value as follows:

$$\Delta X_i = \left(X_i - \bar{X}\right)$$

Step 3: Compute the overall slope standard deviation o-$_S$ based on the above differentials:

$$\sigma_s = \sqrt{\frac{\sum \left(\Delta Y_i\right)^2}{(n-2)\sum \left(\Delta X_i\right)^2}}$$

6.1.3 The normalized standard deviation of the slope is determined using the best-fit straight line slope, *m,* and the slope standard deviation, бs*,* as follows:

Normalized standard deviation of the slope = бs *lm*

6.2 Determination of spectral response linearity

The linearity of the relative spectral response of the test specimen with respect to temperature (or irradiance) for a fixed bias voltage is calculated using the following method.

6.2.1 Calculate the mean value of relative spectral response $\overline{S}_{r\lambda}$ for each wavelength interval. The individual relative spectral response values $S_{r\lambda i}$ used in this calculation are the data points of relative spectral response with respect to

a) irradiance with a fixed temperature, or

b) temperature with a fixed irradiance.

The parameter *n* is the respective number of data points for each of these conditions:

$$\overline{S}_{r\lambda} = \frac{\sum\limits_{i=1}^{n} S_{r\lambda i}}{n}$$

6.2.2 Calculate the SS_r\\ difference between each S_r\j data point and the S_{rX} mean value for the given wavelength interval with fixed temperature (or irradiance), as follows:

$$\Delta S_{r\lambda i} = \left(S_{r\lambda i} - \overline{S}_{r\lambda}\right)$$

6.2.3 Calculate the standard deviation o_x for the given wavelength interval with fixed temperature (or irradiance) as follows:

$$\sigma_{\lambda} = \sqrt{\frac{\Sigma\left(\Delta S_{r\lambda i}\right)^2}{(n-2)}}$$

6.2.4 The percentage variation of relative spectral response is calculated using the wavelength band standard deviation o_x and the mean value of relative spectral response $\overline{S}_{r\lambda}$ for that wavelength interval at the specified bias voltage and fixed temperature (or irradiance).

Percentage variation = $100 \times \sigma_s \,/\, \overline{S}_{r\lambda}$

6.2.5 For each wavelength interval repeat steps 6.2.1 through 6.2.4;

a) for each fixed temperature (with irradiance as a variable);

b) for each fixed irradiance (with temperature as a variable).

6.2.6 Steps 6.2.1 through 6.2.5 should be repeated for other bias voltages of interest.

6.3 Linearity requirements

When a claim is made for a given device to be linear, the applicable range of temperature, irradiance, voltage, or other necessary conditions shall also be stated. The requirements for the acceptable limits of non-linearity (variation) are

a) For the curve of short-circuit current versus irradiance, the normalized standard deviation of the slope *(6s lm)* should be less than 0,02.

b) For the curve of open-circuit voltage versus the logarithm of irradiance, the normalized standard deviation of the slope *(бs lm)* should be less than 0,05.

c) For the curve of open-circuit voltage and short-circuit current versus temperature, the normalized standard deviation of the slope *(бs lm)* should be less than 0,1.

d) The variation of relative spectral response at a specified voltage is less than 5 % for the wavelength band.

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International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 61829 : 1995 Crystalline silicon photovoltaic (PV) array — On-site measurement of I-V characteristics	IS/IEC 61829 :1995 Crystalline silicon photovoltaic (PV) array — On-site measurement of I-V characteristics	Identical

The technical committee has reviewed the provisions of the following International Standards referred to in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60904-6 :1994	Photovoltaic devices — Part 6: Requirements for reference solar modules
IEC 60904-7 :1995	Photovoltaic devices-— Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 :1960 'Rules for rounding off numerical values *(revised)'.The* number of significant places retained in the rounded off value should be the same as that of the specified value in the standard.

Bureau of Indian Standards

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard alongwith amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc No.: ETD 28 (6021).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices:

			Telephones
Central	:	Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	2323 7617 2323 3841
Eastern	:	1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700054	2337 8499, 2337 8561 2337 8626, 2337 9120
Northern	:	SCO 335-336, Sector 34-A, CHANDIGARH 160022	260 3843 260 9285
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